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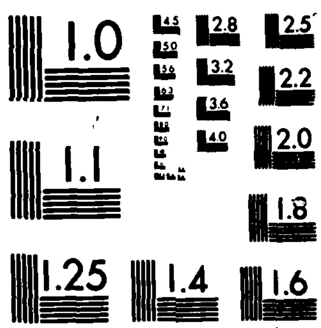

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SEASONAL PHYTOPLANKTON COMPOSITION AND CONCENTRATIONS IN THE LOWER CHESAPEAKE BAY AND VICINITY

By

Harold G. Marshall
Department of Biological Sciences
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Final Report
For the period ending April 15, 1984

Prepared for the
U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, Virginia 23510

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The phytoplankton composition of the lower Chesapeake Bay consisted of a diverse assemblage of 243 species. The major seasonal growth periods were dominated by a diatomaceous flora and a picoplankton complex composed mainly of cyanophytes and chlorophytes.

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INTRODUCTION

The purpose of this study is to characterize the phytoplankton and their seasonal patterns of development in the lower Chesapeake Bay, in an adjacent river estuary, and at a station in shelf waters near the Bay entrance. The river estuary is Hampton Roads, through which the James, Elizabeth, Lafayette, and Nansemond Rivers join to enter the lower Chesapeake Bay. Earlier phytoplankton studies in the lower Chesapeake Bay include Wolfe et al. (1926), Cowles (1930), Mulford (1962, 1963), Mulford and Norcross (1971), Patten et al. (1963), and Marshall (1966, 1967a, 1967b, 1969). Many of the earlier studies stressed the net phytoplankton, where diatoms and dinoflagellates characterized seasonal peaks, which commonly occurred during spring and fall, and to a lesser degree in summer. However, the significance of the nanoplankton component to productivity and total cell concentrations was later emphasized by McCarthy et al. (1974), Van Valkenburg and Flemer (1974), Van Valkenburg et al. (1978), and Marshall (1980). Further comments on the phytoplankton composition of Chesapeake Bay plume were given by Marshall (1982), who noted seasonal differences were distinct enough to characterize the plume in its early movement on the continental shelf.

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METHODS

Monthly water samples were taken for phytoplankton analysis at the surface and a depth one meter above bottom at seven stations between February 1982 and

December 1983 (Figure 1). Two stations (6 and 7) were located in Hampton Roads, one at the entrance of the Elizabeth River, the other in the main channel south of Newport News. In the lower Chesapeake Bay, station 5 was in the main channel northeast of Fort Wool Island, with station 4 located west of the Bay Bridge Tunnel and stations 2 and 3 east of the Bay Bridge, yet still within the inner boundary of the Chesapeake Bay. Station 1 was located seaward approximately 22 km southeast and beyond the Bay Bridge. Standard water bottle casts were made at each station, from which 500 ml of water was preserved immediately with a buffered formalin solution. At two stations (2 and 6), additional samples were taken at both depths and preserved with a modified Lugols solution. For all samples, a settling and siphoning procedure followed to obtain a 40 ml concentrate that was transferred to a settling chamber for examination with an inverted plankton microscope. The entire sample was scanned at 125x for the large net phytoplankton, with a random field and minimum count basis established at 315x for the nanoplankton, and at 500x for the smaller fraction of the picoplankton (0.2-20.0 μm) component (<5 μm), to obtain an 85% accuracy estimate for the last two categories (Venrick, 1978). Cell volume measurements were determined by corresponding each phytoplankter to one or more geometric forms, obtaining mean measurements in samples, and determining cell volume in μm^3. For rarer species, mean values were determined from sample specimens and measurements reported in the literature. Occasional samples were also processed for examination with a scanning electron microscope to aid in species verification. In addition, water temperature and salinity values were obtained at each depth sampled by a Beckman RS-5 Induction Salinometer. Reference to surface samples are those collected within the upper 1 meter of depth. The classification system used follows basically the format given by Hendey (1974) and Parke and Dixon (1976). Station bottom depths ranged from 10 m at station 4, to 17 m at station 1.

Review of the initial species data indicated the seven stations could be combined into four sets, each representing similar areal divisions. These were the

shelf station (1), outer lower Bay stations (2 and 3), inner lower Bay stations (4 and 5), and the Hampton Roads stations (6 and 7). A seasonal combination of surface and bottom results were then made for the species in each set. These are represented in Tables 1-4. However, in graphing the seasonal population patterns for the lower Bay, stations 2-5 were further combined and presented in Figures 4, 7, and 10. The representative salinity and temperature values for the collection period are given in Figure 2 for the shelf station, and selected stations in the lower Bay (station 4) and Hampton Roads (station 7). The seasonal sets were derived by combining and averaging collection data into the four seasons: a) Winter: December, January, February; b) Spring: March, April, May; c) Summer: June, July, August; and d) Fall: September, October, November (see Tables 1-4).

RESULTS

A total of 234 phytoplankters were noted in these collections. They were composed of Bacillariophyceae (125), Dinophyceae (61), Haptophyceae (Prymnesiophyceae) (6), Cyanobacteria (Cyanophyceae) (9), Euglenophyceae (6), Chlorophyceae (11), Cryptophyceae (4), Chrysophyceae (8), and Prasinophyceae (4). In addition, a picoplankton assemblage is included in three unidentified groups, separate from other unidentified taxonomic listings. These cells have been reported before by Marshall (1980, 1982) in the Chesapeake Bay and shelf waters off the Bay entrance. Placed into three size categories (<3, 3-5, and 6-10 μm), they represent a mixture of mainly cyanobacteria (cyanophyceae) and nonflagellated chlorophytes. The importance and ubiquitous nature of this cyanobacteria component in marine waters have been discussed by Waterbury et al. (1979) and Johnson and Sieburth (1979).

The temperature patterns for the seven stations were similar, with peak temperatures occurring in July 1982 and September 1983. However, the 1982 warming trend of summer began earlier and lasted longer in comparison to 1983, before dropping

below 20°C in October. Also in contrast, the May 1983 water temperatures were below those of May 1982. A more extensive warming pattern for the sites did not become established till June 1983. Seasonal temperature lows occurred during February-March (1982) and January-February (1983), with another decline in progress at the end of the study in December 1983. Surface temperatures were typically warmer at station 7 and lowest at the shelf station (1). In general, the decline in water temperatures was accompanied by a decrease in total phytoplankton. The rise in vernal temperatures in 1982 and 1983 were associated with an increase in phytoplankton concentrations. Additional pulses occurred during the late winter and early spring, coinciding with rising salinity values for these stations. As expected, bottom salinity values were greater, with both the surface and bottom salinities consistently higher at the shelf station, averaging 25.5‰ for the surface and 30.2‰ for the bottom samples. The mean values for the lower Bay (station 4) were 21.6 and 25.3‰, and in Hampton Roads 17.8 and 18.4‰, respectively for the surface and bottom samples. Salinity differences appeared to be influenced by the tidal processes in these waters, where the surface waters have a net flow pattern out of the Bay (Pritchard, 1952).

A. Seasonal Distribution Patterns

The total phytoplankton periods of maximum development were similar for the stations in the lower Bay, Hampton Roads, and at the shelf stations (Figures 3, 4, 5). The collections began during a period of declining cell numbers in February 1982. This possibly was an early vernal development that was concluded before an extended growth period could occur. This decrease continued into May, which was then followed by a slight rise in June at all stations. Both of these growth periods were dominated by diatoms. A small pulse was also noted in mid-fall in the lower Bay and Hampton Roads. A major development began to occur in mid-winter at all stations and eventually became the spring outburst for 1983, reaching maxima

during the February-April period. Highest numbers occurred at this time at the Hampton Roads stations. Small sized diatoms and various non-diatom picoplankters were most prominent during this growth period. Cell levels fluctuated during the 1983 summer, to rise again during a major fall outburst. This occurred from August through October and was composed of a combination of non-diatom picoplankters, cyanobacteria, and the small sized diatoms. Although this development was decreasing rapidly into November, there were indications of another increase occurring in December in the lower Bay and Hampton Roads. The seasonal concentration patterns at bottom depths throughout this period, generally mimicked those at the surface. However, there was a trend to have higher concentrations in the bottom samples, and these increased numbers were mainly due to the diatoms. The biomass patterns, depicted by cell volumes, closely followed the seasonal expressions of cell concentrations. Generally, spring and fall maxima were found. However, there were distinct differences in times of initiating and terminating these maxima. Periods of lowest biomass values were generally noted during the summer and early fall. Winter was a period of transition, representing the beginning period for the vernal outburst in 1983, or it may represent an early development, declining into spring, as indicated in 1982.

Seasonal concentrations for species in eastern and western parts of the lower Bay are given in Tables 2 and 3. The eastern stations located along the Bay entrance were characterized throughout the seasons by the diatoms *Asterionella glacialis*, *Biddulphia alternans*, *Biddulphia sinensis*, *Cerataulina pelagica*, *Chaetoceros compressum*, *Chaetoceros decipiens*, *Cyclotella* spp., *Cylindrotheca closterium*, *Ditylum brightwellii*, *Guinardia flaccida*, *Leptocylindrus danicus*, *Leptocylindrus minimus*, *Nitzschia pungens*, *Paralia sulcata*, *Pleurosigma angulatum*, *Rhizosolenia delicatula*, *Rhizosolenia calcar-avis*, *Rhizosolenia fragilissima*, *Rhizosolenia setigera*, *Rhizosolenia stolterfothii*, *Skeletonema costatum*, and *Thalassionema nitzschioides*. Other species included *Ceratium lineatum*,

Prorocentrum compressum, *Prorocentrum micans*, *Prorocentrum minimum*, *Emiliana huxleyi*, *Dictyocha fibula*, *Calycomonas ovalis*, *Calycomonas wolfii*, *Cryptomonas* spp., *Gymnodinium* spp., *Protoperidinion* spp., and a high concentration cyanobacteria and chlorophyte cells (<5 μm). There was a slight decrease in the species represented (162 to 145) moving from the eastern to western Bay stations, with many of the same species characterizing both sections. However, in lower concentrations, were forms more common to shelf waters, e.g. *B. alternans*, *B. sinensis*, *C. decipiens*, and *Guinardia flaccida*. The dominant species in the lower Bay were *Asterionella glacialis* (from fall through spring), *Cyclotella* spp., *Cylindrotheca closterium*, *Leptocylindrus danicus*, *L. minimus*, *Nitzschia pungens*, *Rhizosolenia fragilissima*, *R. delicatula*, *Skeletonema costatum*, *Thalassionema nitzschioides*, *Prorocentrum micans*, *P. minimum*, *Emiliania huxleyi*, *Cryptomonas* spp., *Calycomonas ovalis*, and the cyanobacteria-chlorophyte complex. At all stations within the lower Bay were also numerous picoplankton flagellated cells that were not identified in this series. Their concentrations varied seasonally at the different stations, but were generally found in low concentrations. Many of these cells were prasinophytes, typically *Tetraselmis* spp. and *Heteroselmis* spp. The chrysophytes, *Ochromonas* spp. and *Olisthodiscus* spp. were also sporadically noted in the samples. Other forms included several haptophytes, such as *Hymenomonas* spp. and *Chrysochromulina* spp. Since a complete census was not the major goal of this study, and EM analysis was not programmed for all samples taken in this large sampling program, many of these phytoflagellates were collectively placed in a composite phytoflagellate category. In addition, several *Cyclotella* spp. were noted in the collections, many dominant throughout the year. Isolated examinations during the sampling period indicated the presence of *C. caspia*, *C. glomerata*, *C. meneghiniana*, *C. striata*, and at least one unidentified *Cyclotella* sp. These were collectively grouped during the study under *Cyclotella* spp. to avoid misidentification due to their high numbers and the time factor involved in exact identification. A similar situation

occurred among the smaller *Thalassiosira* species (<10 μm). Separate EM examinations indicated *Thalassiosira oestruppii* var. *venrickae* was abundant during the summer and fall months, with at least one other *Thalassiosira* sp. also common. Since the EM was necessary to identify these cells from one another, they were collectively placed together under *Thalassiosira* spp. in this study.

The outer shelf station had concentration maxima that were similar to the lower Bay and Hampton Roads stations in occurrence (Figures 3, 6, 9). Maximum cell counts at this station were 33.5x10^6 cells/l in October 1983, and were mainly composed of cyanobacteria of the 2-3 micron size range. The dominant species at the shelf station were similar to those found in the lower Bay, with concentrations dominated throughout the year by the diatoms *Asterionella glacilis*, *Cerataulina pelagica*, *Chaetoceros decipiens*, *Cyclotella* spp., *Cylindrotheca closterium*, *Ditylum brightwellii*, *Guinardia flaccida*, *Leptocylindrica danicus*, *L. minimus*, *Nitzschia pungens*, *Rhizosolenia calcar-avis*, *R. delicatula*, *R. fragilissima*, *R. setigera*, *Skeletonema costatum*, and *Thalassionema nitzschioides*. In addition, other characteristic forms were *Gymnodinium* spp., *Prorocentrum micans*, *P. minimum*, *Protoperidinium* spp., *Emiliania huxleyi*, *Cryptomonas* spp., and *Calycomonas ovalis*. Also present in large concentrations were the cyanobacteria and chlorophytes in the <5 μm size category. A similar species assemblage was noted by Marshall (1982) for the Chesapeake Bay plume. Its composition changing, becoming mixed with neritic and pelagic species as the plume moves southward, where it eventually loses its identity. Station 1 is located within the plume pathway as it leaves the Bay entrance area. The two stations within Hampton Roads had the most extensive concentration of total cells of the seven stations during the vernal (11.1-15.3x10^6 cells/l) and autumnal (13.6-16.9x10^6 cells/l) outbursts in 1983 (see Figures 4, 7, 10).

The major species at the Hampton Roads stations were also dominant in the lower Bay. High concentrations were more common during late winter and spring by

several species. These included *Asterionella glacialis*, *Cerataulina pelagica*, *Ditylum brightwellii*, *Nitzschia pungens*, *Rhizosolenia delicatula*, *R. fragilissima*, *R. setigera*, *Thalassiosira aestivalis*, *Thalassiosira nordenskioldii*, *Heterocapsa triquetra*, and *Chlorella* sp. The year round dominants included *Cyclotella* spp., *Leptocylindrus minimus*, *Skeletonema costatum*, *Thalassionema nitzschioides*, *Gymnodinium* spp., *Prorocentrum minimum*, *Cryptomonas* spp., *Calycomonas ovalis*, and an assemblage of cyanobacteria and chlorophytes less than 5 μm in size.

Bacillariophyceae

The seasonal distribution pattern for diatoms consisted of from 4 to 6 major growth periods at the seven stations (Figures 6, 7, 8). At stations 1, 2, and 3 these occurred during early spring, late spring to early summer, and early fall. Within the lower Bay-Hampton Roads complex, the seasonal pulses were muted, and tended to be unimodal, with mainly a February-March maximum. Surface and bottom patterns and composition were similar, with the bottom concentrations generally having the higher cell concentrations. Although there was some variation in species dominance at different stations during the study, the dominent diatoms were mainly small-sized, chain-forming cells. During the late winter-spring outburst the most abundant species included *Skeletonema costatum*, *Leptocylindrus danicus*, *Cerataulina pelagica*, *Cyclotella* spp., *Nitzschia pungens*, *Rhizosolenia fragilissima*, *Thalassiosira nordenskioldii*, and *Asterionella glacialis*. The autumnal outbursts were dominated by *Leptocylindrus minimus*, *Skeletonema costatum*, *Cyclotella* spp., *Thalassionema nitzschioides*, *Rhizosolenia fragilissima*, and *Nitzschia pungens*. During the summer months, *Cyclotella* spp., *Leptocylindrus minimus*, *Skeletonema costatum*, and *Thalassionema nitzschioides* were common. Of note, and included in the *Thalassiosira* spp. category is the first report of *Thalassiosira oestrupii* var. *venrickae*, a small species (5-7 μm), common in the lower Bay and on the shelf. However, the major dominants are similar to those reported in earlier studies of the lower Bay phytoplankton, which would include

Skeletonema costatum, *Nitzschia pungens* (var. *atlantica*), *Asterionella glacialis* (*japonica*), *Leptocylindrus danicus* (Patten et al., 1963; Marshall, 1967a, 1967b, 1980). Variations in times of seasonal peaks would be expected, yet diatom peak development in past studies agree with the present findings of a major winter-early spring development and a fall maxima separated by a summer minimum (Wolf et al., 1926; Patten et al., 1963; Marshall, 1980).

Picoplankton

The picoplankton component was divided into three sub-groups: <3 µm, 3-5 µm, and 6-10 µm, consisting of unidentified cells in these size categories. The majority of cells were 2-3 µm in size, and consisted of cyanobacteria that previously would have been classified within the genus *Anacystis* (or *Microcystis*) in the Cyanophyta. They represent green, non-flagellated cells, circular to ovoid in shape, with a smooth surface. These cells appear to be mainly composed of *Synechococcus* spp. Also seasonally found in this size group are chlorophyte species, mainly *Chlorella* spp., and *Nannochloris atomus*. *Chlorella* spp. were also common in the two other size categories. Other phytoplankton are also represented in these groups, contributing to the high cell numbers in these categories. They would include a variety of phytoflagellates, such as prasinophytes, chrysophytes, and haptophytes.

The picoplankton, often as a mixed taxonomic group, were found at all stations throughout the study and showed seasonal variations in concentrations (Figures 6, 7, 8). There was a major peak in their cell concentrations during the autumnal 1983 outburst, reaching 49.9×10^6 cells/l in October at station 1. This period of high cell count generally extended from August through October (1983), with fluctuations in numbers occurring during this period.

Since many of the early Bay studies used net collection procedures, or because emphasis was placed on the net phytoplankton, the picoplankton category was often not addressed. However, McCarthy et al. (1974) stressed their importance by indicating forms <3-5 μm accounted for 56.6 to 89.6% of the productivity in the Chesapeake Bay. Van Valkenburg and Flemer (1974) noted in the upper Bay that nanoplankton <10 μm were more abundant than net phytoplankton throughout the year, with Van Valkenburg et al. (1978) indicating the most abundant photosynthetic cells were in the 2-5 μm size class. These cells have also been reported as a major constituent of the lower Chesapeake Bay and the Bay plume (Marshall, 1980, 1982). The ubiquitous nature of the picoplankton (cyanobacteria) community in marine habitats was established by Johnson and Sieburth (1979) and Waterbury et al. (1979). Due to difficulties in the identification of these forms in the mass sampling of this study, probably some overlap occurred in the placement of cells in this category, and those in the *Chlorella* "complex" of the chlorophytes, and the coccoid cyanobacteria.

Cyanobacteria

This category does not include *Synechococcus* spp. which have been included in the picoplankton category. This group consists mainly of colonial (e.g., *Gomphosphaeria aponina*) and filamentous (e.g., *Oscillatoria* spp., *Nostoc commune*) cyanobacteria that previously would have been designated cyanophytes. Their lowest concentrations were at the shelf station, where one major peak occurred in August 1983 ($1.4x10^6$ cells/l). Their presence, with increased concentrations, were more common in the lower Bay and Hampton Roads stations. There, major peaks occurred in early spring (both 1982 and 1983), with an extensive development during the 1983 summer (Figures 9, 10, 11). At station 4, a spring-summer expression was maintained from April to September, where cell counts ranged between 0.3 - $0.4x10^6$ cells/l.

Marshall (1967a, 1967b) reported *Oscillatoria* sp. in Elizabeth River, Hampton Roads, and Willoughby Bay collections. A more extensive list of cyanobacteria (cyanophyta) in the plankton were noted in the lower Bay and in the Bay plume (Marshall, 1980, 1982). Marshall et al. (1981) also noted a high incidence of cyanobacteria in the channels common to wetlands of the Virginia Delmarva Peninsula and suggested these fertile sites may be seeding centers for many of the cyanobacteria into the plankton community. The large amount of tidal wetlands within the Bay complex could represent a Bay source for a variety of filamentous and coccoid types.

Dinophyceae

With the exception of February 1982, the shelf dinophycean populations were not highly abundant (Figures 9, 10, 11). Modest pulses were present over the collection period, with lowest values during fall 1982. Over the shelf, the dominant populations consisted mainly of *Ceratium fusus*, *Ceratium lineatum*, *Gymnodinium* spp., *Heterocapsa triquetra*, *Prorocentrum micans*, *Prorocentrum minimum*, and *Protoperidinium* spp. In the lower Bay, high concentrations of *Prorocentrum minimum*, *P. micans*, and *Heterocapsa triquitra* seasonally occurred, with *P. minimum* and *H. triquitra* abundant in Hampton Roads. In general, seasonal patterns were varied, with more distinct pulses progressing from the Bay entrance to the Hampton Roads stations. Two to three growth periods/year were common at these stations. These occurred in early spring (April 1982, 1983), summer (June-August 1982, 1983), and fall (1983).

The importance of *Prorocentrum* spp. and one *Exuviaella* species (later *Prorocentrum*) to the lower Chesapeake Bay phytoplankton was first noted by Wolfe et al. (1926). Patten et al. (1963) found *Prorocentrum micans*, *Ceratium furca*, *C. lineatum*, and *C. tripos* common in the lower Bay throughout the year. Marshall (1967a) found *P. micans* common in Hampton Roads. *Prorocentrum minimum* and *P. micans* have been further emphasized as a major constituent of Bay waters (Tyler

and Seliger, 1978; Marshall, 1980, 1982).

Cryptophyceae

Past studies have indicated when formalin is used as a preservative that many cryptomonad cells are destroyed and the cell counts are not accurate (Throndsen, 1978; Marshall and Cohn, 1983). Thus, concentration values in formalin preserved samples tend to be underestimates. Since formalin was the primary preservative used in the study, more accurate counts for the cryptomonads were sought by using Lugols preservative in additional samples taken at stations 2 and 6. These Lugols samples were the basis of the concentration patterns in Figures 7 and 8. Concentrations were generally a factor of 2 to 4 times greater in the station sample pair containing the Lugols than in the formalin sample. Although the cryptomonads maintained representative populations in the samples throughout the study period, pulses were conspicuous in fall (1982, 1983) and the spring-summer months of 1983 (Figures 6, 7, 8). Highest concentrations were reached (2.7×10^6 cells/l) in July 1983.

Cryptomonas spp. were not mentioned by Wolfe (1926) for the lower Chesapeake Bay, but this genus was recognized by Patten et al. (1963) as a major constituent of the lower Bay. Marshall (1967a, 1967b, 1980, 1982) found *Cryptomonas* spp. throughout the year in Hampton Roads, having a bimodal distribution period of spring and early fall maxima, as well as, being a dominant species in the Elizabeth River, the lower Chesapeake Bay, and within the Bay plume.

Haptophyceae

Composed mainly of coccolithophores, this group was common, but generally in low concentrations at each station. Lowest numbers were associated with declining and lowest temperature of winter months (Figures 9, 10, 11). Various growth expressions, short in duration, but frequently found at each station, were present in spring and summer, and to a lesser degree in fall. Supplementary processing of

samples for scanning electron microscopy examination was used to verify identification of the coccolithophores. However, since routine EM examination of samples was not part of the study, many haptophyceans were not able to be identified to species. This included both coccolithophorids and *Chryschromulina* spp. However, the dominant species throughout the study was *Emiliania huxleyi*. Coccolithophores are not included in the early phytoplankton studies in the lower Chesapeake Bay since frequently either net collections or a non-buffered preservative was used with the sample. In other cases, this size group was evidently not included in the examination process. Marshall (1982) reports on the dominance of *Emiliania huxleyi* in the lower Bay and Bay plume, listing 11 species noted in the plume. However, in an earlier study Marshall (1980) did not report *E. huxleyi* at stations along the eastern shore of the Chesapeake Bay where several other haptophytes (e.g. *Hymenomonas* spp.) were noted.

Other Groups

Commonly represented in the samples were chlorophyceans, euglenophyceans, and chryophyceans. Although many of the chlorophytes (e.g. *Nannochloris atomus*) were included in the picoplankton counts, this category is well represented in the phytoplankton. Common genera include *Chlorella, Ankistrodesmus, Crucigenia, Pediastrum*, and *Scenedesmus*. A *Chlorella* complex was recognized, where cell sizes ranged between 2-8 μm. This group dominated the chlorophyte concentrations, which peaked during the winter and spring months. Many of the rarer chlorophytes are common to fresh waters and their presence is often associated with the increased rainfall and the subsequent runoff and stream flow entry into Bay waters. The euglenoids represented a low, but consistent, population base throughout the study. Both *Euglena* spp. and *Eutreptia* spp. were common at all stations, with the rare presence of *Phacus* sp. and *Trachelomonas* spp. The latter were noted in a resting cell stage. The large numbers of chrysophyceans were almost exclusively represented by *Calycomonas* spp. More sporadic in appearance, and usually associated with the

outer Bay and shelf stations were *Dictyocha fibula* and *Distephanus speculum*, with the occasional presence of *Ochromonas* spp. and *Olisthodiscus* spp. The chrysophytes were most abundant in the late spring and summer months, reaching counts of 1.4×10^6 cells/l in July 1983 at station 5. Larger concentrations were more often associated with Hampton Roads and inner stations of the lower Bay. The prasinophyceae were *Pyramimonas* spp. and *Tetraselmis* spp. Although not noted as a major contributor to the cell counts, these cells were frequently found in the lower Bay stations. These groups deserve further study, along with other pico-phytoflagellates that were not identified.

In addition to phytoplankton, the seston of these waters contained a variety of substances and organisms. These included relict diatom frustules, parts of crustacean exoskeletons, trichomes, pollen, and protozoa. Often noted were ciliated protozoa, including a variety of tintinnids, with the larval stages and adult zooplankton infrequently captured in the hydrocast water samples. The tintinnids were more abundant in the sampling during both summers of the study and in February 1983, whereas, the copepods were more common in fall. Fungal spore cases, phycomycetes, and a variety of ecto-endoparasitic, or symbiotic combinations, also appear. These were mainly noted at station 1, and included the cyanobacteria endosymbiont *Richelia intracellularis* of *Rhizosolenia styliformis*, a protozoan epiphyte on *Chaetoceros coarctatus*, and the presence of chytrids on some diatoms. A high chytrid-*Rhizosolenia stolterfothii* association was also present at station 1 in September 1982. In addition, a considerable amount of detritus and silt were present in the samples, being generally more abundant at the Hampton Roads stations.

CONCLUSIONS

The phytoplankton composition of the lower Bay consisted of a diverse assemblage of 234 species. The major seasonal growth periods were dominated by a diatomaceous flora and a picoplankton complex composed mainly of cyanophytes

and chlorophytes <5 μm in size. The seasonal rhythms of peak and low concentrations of growth go beyond the characteristic bimodal spring-fall model common in temperate waters. Instead there is a pattern of multiple pulses of species, often several in unison, that appear during the year. The trend for maximum concentrations during a spring and fall outburst persists. Yet the onset of the different growth periods varied over the two-year period. These variations showed some relationship to rising and falling seasonal temperatures.

The dominant species are not unique for the lower Chesapeake Bay; they are common constituents of the phytoplankton along the northeast coast of the United States. In comparison to the other annual studies in the lower Bay, there exists a core group of seasonal dominants that have persisted for 50 years (Wolfe et al., 1926; Patten et al., 1963; Marshall, 1967a, 1982). This core population consists of *Skeletonema costatum*, *Leptocylindrus danicus*, *Asterionella glacialis*, among others. Unfortunately there has been no consistent manner of collection, preservation, or emphasis in many of these past studies to note basic trends in composition or succession. However, studies over the past decade have placed considerable emphasis on the pico-plankton component, and the significance of cyanobacteria, cryptomonad, and chlorophyte populations. Greater emphasis needs to be placed on these so-called "lesser lights", and other sub-dominants that seasonally appear within the phytoplankton community. The value of this direction of study will be that these non-core species tend to be more responsive to changing environmental conditions (e.g. perturbations) and may be more useful in determining short term trends or even index species to major population shifts in the phytoplankton community.

It is apparent that to understand the phytoplankton dynamics of this complex area that further data acquisition is advisable. This becomes obvious in the general comparisons of information obtained in this study to many of the past investigations in the area. Those studies of only a year in length, or less

merely present one brief segment of a time series. The value of a long-based study (e.g., 5 years), is that one can more fully identify the natural fluctuations in population composition and concentrations, in contrast to perturbation effects. The present study shows that (what appears to be) "normal" seasonal pulses do vary in their time of initiation, duration, composition, and termination. The standard pattern one would expect and its degree of variation can only be determined by an extended monitoring program.

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Table 1. Average seasonal cell concentrations (no/l) at Station 1, between February 1982 through December 1983.

	W	S	S	F
BACILLARIOPHYCEAE				
Actinoptychus senarius Ehrenberg	13.4	5.6	15.1	13.0
Amphora sp.	3.4	0.0	37696.1	13.0
Asterionella glacialis Castracane	284977.0	10494.3	20190.5	136813.8
Bacillaria paxillifer (Muller) Hendey	64.2	0.0	0.0	121.8
Bacteriastrum delicatulum Cleve	0.0	0.0	130.8	0.0
Bacteriastrum elongatum Cleve	0.0	0.0	1885.0	0.0
Bacteriastrum sp.	0.0	0.0	0.0	51.4
Biddulphia alternans (Bailey) Van Heurck	35.8	2.8	64.3	3830.8
Biddulphia aurita (Lyngbye) Brebisson	0.0	0.0	0.0	179.4
Biddulphia granulata Roper	0.0	13.8	29.8	0.0
Biddulphia mobiliensis (Bailey) Grunow	13.0	0.0	5.5	55.0
Biddulphia sinensis Greville	77.4	19.1	190.0	192.4
Biddulphia sp.	0.0	0.0	5.5	13.0
Campylosira cymbelliformis (Schmidt) Grunow	1765.8	0.0	0.0	1508.0
Cerataulina pelagica (Cleve) Hendey	77654.4	72333.6	512.5	10337.8
Chaetoceros affine Lauder	0.0	0.0	378.8	0.0
Chaetoceros compressum Lauder	240.4	618.8	768.6	49253.6
Chaetoceros costatum Pavillard	0.0	5.5	0.0	0.0
Chaetoceros curvisetum Cleve	173.0	37.5	0.0	1556.2
Chaetoceros danicum Cleve	0.0	619.5	3436.8	621.6
Chaetoceros debile Cleve	150829.6	7043.1	1.0	13951.6
Chaetoceros decipiens Cleve	150784.2	715.8	6119.0	730.2
Chaetoceros didymum Ehrenberg	0.0	0.0	0.0	1029.4
Chaetoceros lorenzianum Grunow	0.0	0.0	13.5	0.0
Chaetoceros pendulum Karsten	6.6	2943.0	8848.1	237.8
Chaetoceros pseudocurvisetum Mangin	0.0	0.0	0.0	45.0
Chaetoceros simile Cleve	18094.2	0.0	0.0	0.0
Chaetoceros sociale Lauder	0.0	277.5	0.0	0.0
Chaetoceros sp.	96521.4	41951.5	99969.3	170917.4
Chaetoceros subtile Cleve	0.0	3351.0	50.8	25.8
Climacodium frauenfeldianum Grunow	0.0	0.0	14.8	0.0
Corethron criophilum Castracane	2120.6	629.5	0.0	13468.2
Coscinodiscus centralis Ehrenberg	3818.0	0.0	0.0	2812.6
Coscinodiscus lineatus Ehrenberg	0.0	160.6	0.0	0.0
Coscinodiscus marginatus Ehrenberg	0.0	0.0	0.0	13.0
Coscinodiscus nitidus Gregory	25.8	0.0	0.0	0.0
Coscinodiscus oculus iridis Ehrenberg	2.1	0.0	0.0	0.0
Coscinodiscus radiatus Ehrenberg	0.0	10.8	0.0	0.0
Coscinodiscus sp.	195.4	372.1	52.5	834.0
Coscinodiscus wailesii Gran and Angst	0.0	20.1	0.0	0.0
Coscinosira polychorda (Gran) Gran	173.2	37.6	0.0	0.0
Cyclotella spp.	77717.8	893738.8	369852.8	127568.8
Cylindrotheca closterium (Ehrenberg) Reiman and Lewin	12315.0	4567.3	16955.1	3571.4

Table 1. (continued)

	W	S	S	F
Ditylum brightwellii (West) Grunow	37052.0	2835.8	345.0	3672.4
Eucampia zoodiacus Ehrenberg	358.6	0.0	0.0	7707.6
Fragilaria sp.	323.4	472.3	0.0	0.0
Grammatophora sp.	1334.4	2513.1	5026.3	419.0
Guinardia flaccida (Castracane) Peragallo	3192.4	12855.5	377.0	816.8
Gyrosigma fasciola (Ehrenberg) Cleve	0.0	5.5	1.5	0.0
Hemiaulus sinensis Greville	1371.0	0.0	64.3	3028.8
Hemiaulus sp.	0.0	0.0	0.0	25.8
Leptocylindrus danicus Cleve	1974769.8	68272.1	94478.6	71000.4
Leptocylindrus minimus Gran	17167.8	358842.0	154651.0	74592.6
Licmophora sp.	51.4	8.1	0.0	0.0
Lithodesmium undulatum Ehrenberg	580.2	0.0	53.6	423.0
Navicula distans (W. Smith) Cleve	0.0	0.0	0.0	128.2
Navicula sp.	0.0	10.8	0.0	0.0
Nitzschia delicatissima Cleve	0.0	149.5	0.0	22732.4
Nitzschia longissima (Brebisson) Ralfs	0.0	0.0	0.0	13.0
Nitzschia pungens Grunow	180457.0	88185.0	43203.6	203855.0
Nitzschia seriata Cleve	653.2	1505.0	780.8	118.6
Paralia sulcata (Ehrenberg) Cleve	12931.4	7414.3	254.0	653.8
Plagiogramma staurophorum (Gregory) Heilberg	368.8	0.0	5.5	0.0
Pleurosigma angulatum (Quekett) W. Smith	324.2	5088.6	175.5	74.2
Pleurosigma sp.	1330.2	689.6	87.6	499.8
Rhaphoneis amphiceros Ehrenberg	410.6	37.8	33.8	516.0
Rhaphoneis sp.	0.0	13.6	2.8	0.0
Rhaphoneis surirella (Ehrenberg) Grunow	2793.6	69.5	0.0	1846.6
Rhizosolenia alata Brightwell	1598.8	19.1	3338.0	3110.4
Rhizosolenia alata f. *gracillima* (Cleve) Grunow	2741.8	0.0	64.1	16.4
Rhizosolenia alata f. *indica* (Peragallo) Gran	0.0	0.0	1.6	0.0
Rhizosolenia calcar-avis Schultze	391.6	160.8	969.5	701.8
Rhizosolenia delicatula Cleve	169691.4	102543.8	22034.8	50946.4
Rhizosolenia fragilissima Bergon	121416.0	365721.8	14112.5	125462.6
Rhizosolenia hebetata f. *semispina* (Hensen) Gran	326.6	0.0	0.0	0.0
Rhizosolenia imbricata Brightwell	2288.0	7437.6	564.0	13031.4
Rhizosolenia setigera Brightwell	32147.0	13268.1	142.0	36015.8
Rhizosolenia stolterfothii Peragallo	2889.4	1312.3	2131.6	270556.8
Rhizosolenia styliformis Brightwell	0.0	0.0	0.0	1219.4
Schroederella delicatula (Peragallo) Pavillard	38.6	96.1	85.5	3249.8
Skeletonema costatum (Greville) Cleve	1469128.2	311867.8	630079.3	1138143.5
Staphanopyxis palmeriana (Greville) Grunow	0.0	0.0	5.5	0.0
Stephanopyxis turris (Greville) Ralfs	0.0	2.8	0.0	368.6
Tabellaria fenestrata (Lyngbye) Kutzing	0.0	0.0	704.1	1459.4
Thalassionema nitzschioides Hustedt	77162.4	11389.8	239389.5	77194.6
Thalassiosira aestivalis Gran and Angst	2262.0	11759.6	0.0	0.0
Thalassiosira decipiens (Grunow) Jorgensen	5232.6	0.0	0.0	0.0
Thalassiosira gravida Cleve	4195.2	128.3	2340.1	288.6
Thalassiosira nordenskioldii Cleve	3317835.8	15719.3	0.0	0.0

Table 1. (continued)

	W	S	S	F
Thalassiosira rotula Meunier	24189.8	42.8	0.0	0.0
Thalassiosira spp.	10487.0	3077.0	285630.6	130215.2
Centric diatoms <20 µm	81920.2	388815.5	170923.0	92261.6
Centric diatoms >20 - <100 µm	17093.2	14128.8	5317.1	2412.8
Pennate diatoms <20 µm	41071.2	36037.5	134708.3	77997.0
Pennate diatoms >20 µm	18907.0	4714.3	39841.8	17910.6
DINOPHYCEAE				
Amphidinium acutissimum Schiller	4122.2	10.8	1.5	0.0
Amphidinium acutum Lahmann	102.6	0.0	0.0	0.0
Amphidinium sp.	0.0	6973.5	0.0	0.0
Ceratium extensum (Gourret) Cleve	3.4	0.0	0.0	0.0
Ceratium fusus (Ehrenberg) DuJardin	45.4	294.3	12.6	77.0
Ceratium lineatum (Ehrenberg) Cleve	160.8	529.1	411.6	829.8
Ceratium macroceros (Ehrenberg) VanHoffen	0.0	0.0	16.5	0.0
Ceratium massiliense (Gourret) Jorgensen	45.0	0.0	5.5	13.0
Ceratium trichoceros (Ehrenberg) Kofoid	0.0	0.0	0.0	3.4
Ceratium tripos (Muller) Nitzsch	0.0	1370.3	142.0	0.0
Cochlodinium sp.	0.0	0.0	5654.6	0.0
Dinophysis acuta Ehrenberg	0.0	131.1	2.8	0.0
Dinophysis monacantha Kofoid and Skogsberg	0.0	2.8	0.0	0.0
Dinophysis ovum Schutt	13.2	0.0	0.0	0.0
Dinophysis punctata Jorgensen	13.0	0.0	5.5	3.4
Dinophysis sp.	51.8	281.0	24.6	0.0
Dinophysis tripos Gourret	3.4	0.0	0.0	0.0
Gonyaulax monocantha Pavillard	0.0	0.0	53.5	0.0
Gonyaulax sp.	0.0	197.8	91.1	0.0
Gonyaulax spinifera (Claparede and Lachmann) Diesing	0.0	0.0	0.0	13.0
Gonyaulax tricantha Jorgensen	0.0	0.0	0.0	38.6
Gymnodinium nelsonii Martin	0.0	0.0	408.5	13.0
Gymnodinium sp.	15385.0	40918.8	18652.5	19664.2
Gyrodinium sp.	1118.8	2978.8	1189.6	422.6
Heterocapsa triquetra (Ehrenberg) Stein	760.8	2767.8	0.0	1206.4
Noctiluca miliaris Suriray	0.0	0.0	0.0	45.2
Prorocentrum compressum (Bailey) Abe	545.0	0.0	326.3	461.2
Prorocentrum micans Ehrenberg	138.4	3570.5	5968.3	154.2
Prorocentrum minimum (Pavillard) Schiller	79915.8	35678.3	5655.0	77.2
Prorocentrum sp.	0.0	85.5	0.0	0.0
Prorocentrum triestinum Schiller	11312.6	0.0	0.0	154.2
Protoperidinium bipes (Paulsen) Balech	0.0	43.0	0.0	0.0
Protoperidinium breve (Paulsen) Balech	19.4	0.0	0.0	0.0
Protoperidinium brevipes (Paulsen) Balech	0.0	0.0	37.6	294.6
Protoperidinium depressum (Bailey) Balech	68.0	86.3	0.0	51.6
Protoperidinium diabolim (Cleve) Balech	0.0	0.0	29.5	0.0
Protoperidinium granii (Ostenfeld) Balech	6.6	32.3	184.6	0.0
Protoperidinium oceanicum (Vanhoffen) Balech	16.4	0.0	5.5	0.0
Protoperidinium ovatum Pouchet	0.0	22.1	0.0	0.0

Table 1. (continued)

	W	S	S	F
Protoperidinium pallidum (Ostenfeld) Balech	0.0	26.8	0.0	0.0
Protoperidinium sp.	8643.0	2362.6	4401.5	2581.6
Pyrocystis sp.	0.0	2.8	0.0	0.0
Pyrophacus horologium Stein	0.0	0.0	10.8	0.0
Scrippsiella trochoidea (Stein) Loeblich III	0.0	0.0	0.0	64.2
Dinoflagellate cysts	10.0	2212.3	48.3	13.0
Unidentified dinoflagellates	0.0	0.0	0.0	10.1
HAPTOPHYCEAE				
Anthosphaera sp.	0.0	0.0	1890.5	0.0
Calciosolenia granii Schiller	0.0	0.0	1.5	0.0
Cyclococcolithus leptopora (Murray and Blackman) Kamptner	0.0	320.2	292.4	0.0
Emiliania huxleyi (Lohmann) Hay and Mohler	10439.4	31013.0	21295.3	18641.6
Rhabdosphaera hispida Lohmann	0.0	1713.6	0.0	0.0
Rhabdosphaera sp.	0.0	0.0	0.0	1675.8
Syracosphaera pulchra Lohmann	0.0	18.6	0.0	0.0
Unidentified coccolithophores	0.0	0.0	1593.3	20270.8
CHRYSOPHYCEAE				
Calycomonas ovalis Wulf	55312.2	250630.8	204890.0	30796.2
Calycomonas wulfii Conrad and Kufferath	0.0	13175.1	12649.0	0.0
Dictyocha fibula Ehrenberg	0.0	2.8	1557.8	13.0
Distephanus speculum (Ehrenberg) Haekel	38.6	2.8	2.8	0.0
CYANOBACTERIA				
Gomphosphaera aponina Kutzing	5272.4	1256.6	12566.0	2154.2
Merismopedia sp.	0.0	2.8	0.0	0.0
Microcystis spp.	409.8	68710.5	248793.3	384.2
Nostoc commune Vaucher	0.0	0.0	0.0	1920.2
Oscillatoria sp. #1	0.0	0.0	0.0	70.8
Oscillatoria sp. #2	0.0	0.0	12006.5	0.0
Richelia intracellularis Schmidt	0.0	0.0	0.0	120.2
EUGLENOPHYCEAE				
Euglena sp.	25.8	4549.6	1322.8	3532.0
Eutreptia lanowii Steuer	0.0	0.0	0.0	128.2
Eutreptia sp.	0.0	0.0	256.3	425.6
Eutreptia viridis Perty	1413.2	192.3	2674.6	358.8

Table 1. (continued)

	W	S	S	F
CHLOROPHYCEAE				
Ankistrodesmus sp.	0.0	21.8	0.0	0.0
Chlorella sp. #1	5859.2	10850.0	3426.3	0.0
Chlorella sp. #2	0.0	35183.1	0.0	0.0
Pediastrum simplex (Meyen) Lemmermann	0.0	0.0	0.0	13.0
Scenedesmus acumin (Laberheim) Chodat	102.6	0.0	0.0	0.0
CRYPTOPHYCEAE				
Cryptomonas spp.	64595.8	68844.1	108028.0	100661.2
PRASINOPHYCEAE				
Pyramimonas sp.	6.6	0.0	7539.5	0.0
OTHERS (PICOPLANKTON)				
Green cells (<3 μm)	1811270.0	2882832.1	2603813.8	3295304.8
Green cells (3-5 μm)	245282.0	247059.6	152790.5	129303.2
Green cells (5-10 μm)	120620.2	81529.5	70667.8	34268.5
Micro-phytoflagellates (<10 μm)	4592.6	11728.2	19543.0	29819.8

Table 2. Average seasonal cell concentrations (no/l) at Stations 2 and 3, between February 1982 through December 1983.

	W	S	S	F
BACILLARIOPHYCEAE				
Achnanthes longipes Agardh	0.0	42.7	0.0	0.0
Actinoptychus senarius Ehrenberg	12.3	317.0	12.3	6.9
Amphora sp.	0.0	1.4	1.4	0.0
Asterionella glacialis Castracane	126967.8	28109.2	5435.2	14773.4
Bacillaria paxillifer (Muller) Hendey	16.1	0.0	0.0	144.1
Bacteriastrum delicatulum Cleve	0.0	0.0	220.3	0.0
Bellochea horologicalis Von Stosch	0.0	0.0	0.0	10.8
Biddulphia alternans (Bailey) Van Heurck	52.3	5.4	21.4	593.8
Biddulphia granulata Roper	12.3	8.3	13.5	0.0
Biddulphia mobiliensis (Bailey) Grunow	0.0	0.0	16.0	32.3
Biddulphia sinensis Greville	70.5	10.9	133.7	236.2
Biddulphia sp.	0.0	0.0	4.1	18.9
Campylosira cymbelliformis (Schmidt) Grunow	12.1	0.0	0.0	0.0
Cerataulina pelagica (Cleve) Hendey	33422.2	43157.3	263.0	10749.5
Chaetoceros affine Lauder	0.0	0.0	221.5	0.0
Chaetoceros compressum Lauder	1448.6	877.5	591.0	6152.4
Chaetoceros curvisetum Cleve	102.1	0.0	32.0	400.3
Chaetoceros danicum Cleve	8.2	1474.1	4819.8	986.3
Chaetoceros debile Cleve	153007.5	3368.0	0.0	5660.1
Chaetoceros decipiens Cleve	37696.2	29.4	4344.8	805.9
Chaetoceros didymum Ehrenberg	0.0	0.0	0.0	1682.7
Chaetoceros lorenzianum Grunow	0.0	0.0	6.7	0.0
Chaetoceros neogracile Van Landingham	0.0	0.0	2789.7	77.8
Chaetoceros pendulum Karsten	2.1	347.0	2444.3	230.1
Chaetoceros pseudocurvisetum Mangin	0.0	0.0	0.0	88.0
Chaetoceros sp.	51844.6	21272.9	32420.5	109075.2
Chaetoceros subtile Cleve	0.0	1142.4	16.0	10.7
Climadocium frauenfeldianum Grunow	0.0	0.0	13.4	0.0
Corethron criophilum Castracane	118.6	349.0	0.0	13051.9
Coscinodiscus centralis Ehrenberg	1535.5	0.0	0.0	2118.0
Coscinodiscus lineatus Ehrenberg	0.0	386.5	0.0	0.0
Coscinodiscus marginatus Ehrenberg	0.0	0.0	0.0	26.9
Coscinodiscus sp.	361.0	208.0	821.9	773.3
Coscinodiscus wailesii Gran and Angst	0.0	1.4	0.0	0.0
Coscinosira polychorda (Gran) Gran	590.5	5.4	0.0	0.0
Cyclotella spp.	65897.3	434322.1	267087.3	241259.5
Cylindrotheca closterium (Ehrenberg) Reiman and Lewin	4253.5	3689.6	8933.5	41729.9
Ditylum brightwellii (West) Grunow	32136.5	2352.5	98.1	2133.5
Eucampia zoodiacus Ehrenberg	24.1	0.0	37.4	8614.9
Fracilaria sp.	452.3	221.5	0.0	0.0

Table 2. (continued)

	W	S	S	F
Grammatophora sp.	5654.7	2113.5	2513.1	314.2
Guinardia flaccida (Castracane) Peragallo	2629.0	6129.0	5042.3	845.0
Gyrosigma fasciola (Ehrenberg) Cleve	26.2	0.0	0.0	0.0
Hemiaulus hauckii Grunow	0.0	0.0	10.7	1256.5
Hemiaulus sinensis Greville	0.0	0.0	26.8	1547.3
Hemiaulus sp.	0.0	0.0	10.7	0.0
Leptocylindrus danicus Cleve	38419.3	109204.5	90430.0	28006.3
Leptocylindrus minimus Gran	403398.8	107674.4	81008.9	133017.0
Licmophora sp.	4.1	374.9	0.0	0.0
Lithodesmium sp.	0.0	0.0	0.0	10.7
Lithodesmium undulatum Ehrenberg	20.3	0.0	53.5	122.4
Melosira nummuloides (Dillwyn) Agardh	0.0	24.0	0.0	0.0
Navicula distans (W. Smith) Cleve	0.0	0.0	0.0	181.4
Nitzschia delicatissima Cleve	0.0	0.0	0.0	17099.4
Nitzschia longissima (Brebisson) Ralfs	0.0	0.0	0.0	5.4
Nitzschia pungens Grunow	389747.3	70996.5	29121.3	25882.5
Nitzschia seriata Cleve	2578.3	220.1	66.8	96.3
Paralia sulcata (Ehrenberg) Cleve	2655.3	3838.0	66.9	2002.2
Plagiogramma staurophorum (Gregory) Heilberg	214.2	0.0	0.0	0.0
Pleurosigma angulatum (Quekett) W. Smith	160.8	2703.5	144.5	71.3
Pleurosigma naviculaceum Brebisson	2.1	0.0	0.0	0.0
Pleurosigma sp.	569.3	336.9	39.0	59.0
Rhaphoneis amphiceros Ehrenberg	260.8	2.7	28.3	48.5
Rhaphoneis sp.	2.1	19.0	1.4	0.0
Rhaphoneis surirella (Ehrenberg) Grunow	1737.7	0.0	0.0	3685.4
Rhizosolenia alata Brightwell	66.7	8.1	482.5	1847.3
Rhizosolenia alata f. *gracillima* (Cleve) Grunow	0.0	0.0	112.1	37.6
Rhizosolenia alata f. *indica* (Peragallo) Gran	0.0	0.0	0.0	10.7
Rhizosolenia calcar-avis Schultze	731.0	126.0	463.4	2338.3
Rhizosolenia delicatula Cleve	58986.6	53268.4	8575.4	28502.2
Rhizosolenia fragilissima Bergon	62682.5	375428.8	9622.4	11351.6
Rhizosolenia imbricata Brightwell	571.0	3163.0	38.9	3018.5
Rhizosolenia setigera Brightwell	6944.8	3985.1	20.3	1634.2
Rhizosolenia stolterfothii Peragallo	208.2	42.7	363.1	105679.5
Rhizosolenia styliformis Brightwell	0.0	0.0	0.0	897.5
Schroederella delicatula (Peragallo) Pavillard	482.8	9.4	0.0	1341.1
Skeletonema costatum (Greville) Cleve	355272.2	264640.3	1121235.0	202219.5
Stephanopyxis palmeriana (Greville) Grunow	0.0	0.0	40.1	0.0
Staphanopyxis turris (Greville) Ralfs	0.0	0.0	0.0	284.5
Striatella sp.	0.0	314.2	0.0	330.7
Surirella sp.	0.0	0.0	2.7	0.0
Tabellaria fenestrata (Lyngbye) Kutzing	0.0	0.0	24259.7	200.1
Thalassionema nitzschioides Hustedt	21272.1	4299.2	222337.0	26354.0
Thalassiosira aestivalis Gran and Angst	476.5	4956.0	0.0	0.0
Thalassiosira decipiens (Grunow) Jorgensen	36.1	0.0	0.0	0.0
Thalassiosira gravida Cleve	166.5	26.8	14012.4	232.2

Table 2. (continued)

	W	S	S	F
Thalassiosira nordenskioldii Cleve	568179.6	3536.0	0.0	0.0
Thalassiosira rotula Meunier	212.1	38.9	0.0	1894.3
Thalassiosira spp.	20225.3	3916.6	57538.6	42197.2
Thalassiothrix frauenfeldii Grunow	176.1	0.0	0.0	0.0
Triceratium sp.	0.0	5.4	0.0	0.0
Centric diatoms <20 µm	76478.0	225244.2	135506.7	102770.9
Centric diatoms >20 - <100 µm	18863.0	3504.0	574.0	867.7
Pennate diatoms <20 µm	23846.5	20036.7	81932.6	190539.3
Pennate diatoms >20 µm	12880.2	3391.5	15631.5	11291.3
DINOPHYCEAE				
Amphidinium acutissimum Schiller	1054.7	0.0	0.0	0.0
Amphidinium acutum Lahmann	400.3	0.0	0.0	0.0
Amphidinium sp.	16930.0	4495.8	0.0	0.0
Ceratium fusus (Ehrenberg) DuJardin	20.2	79.0	6.9	0.0
Ceratium lineatum (Ehrenberg) Cleve	14.5	115.4	199.3	1066.0
Ceratium macroceros (Ehrenberg) VanHoffen	0.0	0.0	6.8	0.0
Ceratium massiliense (Gourret) Jorgensen	0.0	0.0	8.1	0.0
Ceratium teres Kofoid	6.1	0.0	0.0	0.0
Ceratium tripos (Muller) Nitzsch	4.1	400.8	63.1	0.0
Cladopyxis caryophyllum (Kofoid) Pavillard	0.0	5.4	0.0	0.0
Cochlodinium sp.	0.0	0.0	2199.0	0.0
Dinophysis acuta Ehrenberg	0.0	45.6	1.4	0.0
Dinophysis caudata Kent	0.0	0.0	0.0	5.4
Dinophysis punctata Jorgensen	16.3	0.0	77.5	5.5
Dinophysis sp.	98.5	172.7	80.3	10.7
Dinophysis tripos Gourret	2.1	0.0	0.0	0.0
Diplopeltopsis minor (Paulsen) Pavillard	0.0	0.0	2.7	0.0
Gonyaulax sp.	0.0	53.4	338.5	0.0
Gonyaulax tricantha Jorgensen	0.0	0.0	0.0	16.0
Gymnodinium nelsonii Martin	0.0	0.0	208.2	5.4
Gymnodinium sp.	6430.0	20490.3	24962.8	23467.8
Gyrodinium sp.	1547.2	1266.5	5.4	1708.9
Heterocapsa triquetra (Ehrenberg) Stein	2548.5	2931.0	0.0	6736.9
Katodinium sp.	0.0	0.0	0.0	418.9
Noctiluca miliaris Suriray	0.0	0.0	0.0	59.0
Oxytoxum sp.	0.0	0.0	0.0	2.7
Prorocentrum compressum (Bailey) Abe	290.8	16.2	192.4	256.1
Prorocentrum micans Ehrenberg	1939.6	5583.0	14674.9	451.5
Prorocentrum minimum (Pavillard) Schiller	17968.2	26844.5	4341.2	8836.1
Prorocentrum triestinum Schiller	224.3	0.0	0.0	3677.4
Protoperidinium bipes (Paulsen) Balech	0.0	38.8	5.4	0.0
Protoperidinium breve (Paulsen) Balech	0.0	0.0	0.0	10.8
Protoperidinium brevipes (Paulsen) Balech	0.0	0.0	13.5	122.7

Table 2. (continued)

	W	S	S	F
Protoperidinium conicoides (Paulsen) Balech	0.0	0.0	0.0	5.4
Protoperidinium conicum (Gran) Balech	0.0	0.0	2.7	0.0
Protoperidinium depressum (Bailey) Balech	4.1	48.5	0.0	57.7
Protoperidinium diabolim (Cleve) Balech	0.0	0.0	5.4	0.0
Protoperidinium granii (Ostenfeld) Balech	40.3	56.3	51.0	4.1
Protoperidinium mite (Pavillard) Balech	168.1	0.0	0.0	0.0
Protoperidinium oceanicum (VanHoffen) Balech	8.2	0.0	8.1	14.8
Protoperidinium sp.	3673.3	1546.5	2979.9	3952.5
Scripsiella trochoidea (Stein) Loeblich III	0.0	0.0	0.0	48.1
Dinoflagellate cysts	1059.0	1302.3	40.1	478.0
Unidentified dinoflagellates	0.0	0.0	0.0	2.0
HAPTOPHYCEAE				
Anthosphaera sp.	0.0	0.0	942.5	0.0
Calciosolenia granii Schiller	0.0	0.0	0.0	2.7
Emiliania huxleyi (Lohmann) Hay and Mohler	1913.6	13554.9	21218.9	7094.9
Michaelsarsia elegans Gran	0.0	0.0	0.0	628.3
Rhabdosphaera hispida Lohmann	314.2	2309.8	571.2	0.0
Rhabdosphaera sp.	0.0	0.0	0.0	340.0
Unidentified coccolithophores	0.0	0.0	628.3	7817.8
CHRYSOPHYCEAE				
Calycomonas ovalis Wulff	45273.7	130937.5	234454.4	61570.1
Calycomonas wulfii Conrad and Kufferath	3662.1	5897.1	26804.2	4882.5
Dictyocha fibula Ehrenberg	2.1	1.4	5956.4	424.3
Distephanus speculum (Ehrenberg) Haekel	12.2	207.2	0.0	0.0
CYANOBACTERIA				
Anacystis sp. #1	0.0	0.0	5918.1	0.0
Anacystis sp. #2	0.0	0.0	130051.0	0.0
Dactylococcopsis rhaphidioides Hansgrig	0.0	5.4	0.0	0.0
Gomphosphaera aponina Kutzing	4.1	628.3	4712.1	4248.5
Microcystis spp.	1413.7	67678.6	351544.2	533.5
Nostoc commune Vaucher	0.0	0.0	0.0	800.0
Oscillatoria sp.	0.0	0.0	0.0	2.7
Unknown blue green trichomes	2.1	0.0	97925.6	0.0
EUGLENOPHYCEAE				
Euglena sp.	16.1	3116.9	0.0	1471.5
Eutreptia lanowii Steuer	0.0	0.0	0.0	5.4
Eutreptia sp.	942.5	0.0	1411.6	209.4
Eutreptia viridis Perty	58.6	117.7	3477.9	2185.0

Table 2. (continued)

	W	S	S	F
CHLOROPHYCEAE				
Ankistrodesmus sp.	0.0	4.1	0.0	0.0
Chlorella sp. #1	20750.5	9764.9	8137.4	0.0
Chlorella sp. #2	0.0	74135.6	0.0	0.0
Pediastrum simplex (Meyen) Lemmermann	0.0	0.0	0.0	5.4
Scenedesmus acumin (Lagerheim) Chodat	24.1	0.0	0.0	0.0
CRYPTOPHYCEAE				
Cryptomonas spp.	37754.0	32970.5	102027.6	198942.2
PRASINOPHYCEAE				
Pyramimonas sp.	4.1	0.0	5940.1	0.0
Pyramimonas torta Conrad and Kufferath	0.0	0.0	0.0	4816.8
OTHERS (PICOPLANKTON				
Green cells <3 μm	1441974.1	1667193.8	1834797.4	3311037.1
Green cells 3-5 μm	66889.1	122105.7	379033.9	80626.6
Green cells 5-10 μm	28222.6	69581.5	43350.7	12280.7
Micro-phytoflagellates <10 μm	3827.5	2524.0	36526.7	15697.5

Table 3. Average seasonal cell concentrations (no/l) at Stations 4 and 5, between February 1982 through December 1983.

	W	S	S	F
BACILLARIOPHYCEAE				
Achnanthes sp.	305.3	0.0	0.0	0.0
Actinoptychus senarius Ehrenberg	4.1	21.6	20.2	4.1
Amphiprora sp.	0.0	0.0	0.0	2.7
Amphora sp.	458.3	9.5	10.7	0.0
Asterionella glacialis Castracane	187682.5	42058.7	120.2	4779.8
Bacillaria paxillifer (Muller) Hendey	0.0	0.0	0.0	2.7
Bacteriastrum delicatulum Cleve	0.0	0.0	10.7	0.0
Bellochea horologicalis Von Stosch	0.0	0.0	0.0	14.7
Biddulphia alternans (Bailey) Van Heurck	12.2	10.8	0.0	26.9
Biddulphia granulata Roper	4.1	6.9	4.0	2.7
Biddulphia mobiliensis (Bailey) Grunow	0.0	0.0	29.6	16.1
Biddulphia regia (Schultz) Ostenfeld	0.0	0.0	0.0	2.7
Biddulphia sinensis Greville	14.3	8.2	10.8	23.0
Biddulphia sp.	0.0	0.0	0.0	16.2
Campylosira cymbelliformis (Schmidt) Grunow	0.0	6.7	0.0	5.4
Cerataulina pelagica (Cleve) Hendey	5426.8	88714.1	1840.5	1471.8
Chaetoceros compressum Lauder	14432.2	34300.0	1059.9	10808.3
Chaetoceros curvisetum Cleve	20.1	16.0	48.0	17.4
Chaetoceros danicum Cleve	12.1	704.3	1954.5	85.6
Chaetoceros debile Cleve	523829.0	15185.5	0.0	37.4
Chaetoceros decipiens Cleve	0.0	6000.8	77.5	18228.0
Chaetoceros neogracile Van Landingham	0.0	1884.9	2719.8	643.0
Chaetoceros pendulum Karsten	16.2	2030.3	181.9	37.7
Chaetoceros sociale Lauder	1221.0	0.0	0.0	0.0
Chaetoceros sp.	6929.8	26967.8	52390.1	11442.1
Chaetoceros subtile Cleve	5160.6	12565.4	12284.7	61.5
Corethron criophilum Castracane	44.5	16.1	0.0	14509.4
Coscinodiscus centralis Ehrenberg	1245.3	0.0	0.0	374.8
Coscinodiscus lineatus Ehrenberg	0.0	325.0	0.0	0.0
Coscinodiscus marginatus Ehrenberg	0.0	37.4	0.0	5.4
Coscinodiscus radiatus Ehrenberg	0.0	0.0	10.7	0.0
Coscinodiscus sp.	174.5	450.9	893.5	923.9
Coscinosira polychorda (Gran) Gran	676.5	32.1	0.0	0.0
Cyclotella spp.	52411.7	605831.8	312861.9	167804.9
Cylindrotheca closterium (Ehrenberg) Reiman and Lewin	2731.6	2989.5	37043.0	20519.6
Diploneis sp.	0.0	0.0	0.0	1.4
Ditylum brightwellii (West) Grunow	45112.1	3704.8	133.9	1020.9
Eucampia zoodiacus Ehrenberg	0.0	20.1	9.4	1191.8
Fragilaria sp.	592.2	292.3	0.0	0.0
Grammatophora sp.	7792.0	3174.5	2303.7	0.0
Guinardia flaccida (Castracane) Peragallo	375.0	353.8	77.5	17.5

Table 3. (continued)

	W	S	S	F
Gyrosigma fasciola (Ehrenberg) Cleve	237.0	6.9	1.4	207.1
Leptocylindrus danicus Cleve	22186.2	20797.2	30864.5	3209.3
Leptocylindrus minimus Gran	32897.2	82556.8	293444.6	137759.8
Licmophora sp.	4.1	2.8	0.0	2.7
Lithodesmium undulatum Ehrenberg	0.0	0.0	0.0	51.0
Navicula cancellata Donkin	4.1	0.0	0.0	0.0
Navicula sp.	4.1	0.0	10.7	0.0
Nitzschia delicatissima Cleve	0.0	2617.8	176.0	64.0
Nitzschia longissima (Brebisson) Ralfs	0.0	0.0	0.0	1090.0
Nitzschia pungens Grunow	549526.3	183940.7	3503.0	1570.7
Nitzschia seriata Cleve	88.1	165.5	5045.0	0.0
Nitzschia spathulata Brebisson	0.0	5.4	0.0	0.0
Paralia sulcata (Ehrenberg) Cleve	2074.2	1204.9	272.5	734.1
Plagiogramma staurophorum (Gregory) Heilberg	4.1	0.0	5.4	0.0
Pleurosigma angulatum (Quekett) W. Smith	319.0	4727.0	416.7	230.0
Pleurosigma sp.	164.8	119.5	56.3	31.1
Rhaphoneis amphiceros Ehrenberg	40.6	10.8	21.5	18.9
Rhaphoneis sp.	0.0	5.5	4.0	0.0
Rhaphoneis surirella (Ehrenberg) Grunow	68.0	74.9	0.0	465.8
Rhizosolenia alata Brightwell	0.0	11.0	40.1	166.3
Rhizosolenia alata f. *gracillima* (Cleve) Grunow	261.8	0.0	0.0	21.5
Rhizosolenia calcar-avis Schultze	857.0	188.5	88.6	563.2
Rhizosolenia delicatula Cleve	38171.5	40238.3	1052.6	4908.9
Rhizosolenia fragilissima Bergon	138514.3	437196.8	3268.0	4585.7
Rhizosolenia imbricata Brightwell	96.5	414.0	2.7	368.2
Rhizosolenia setigera Brightwell	6751.2	4368.2	37.4	1271.2
Rhizosolenia stolterfothii Peragallo	380.8	16.0	34.8	37226.4
Schroederella delicatula (Peragallo) Pavillard	168.5	100.1	0.0	32.0
Skeletonema costatum (Greville) Cleve	196501.2	514159.6	520257.1	67042.5
Stephanopyxis turris (Greville) Ralfs	0.0	1.4	0.0	17.5
Streptotheca thamensis Shrubsole	0.0	0.0	0.0	26.8
Striatella sp.	0.0	314.2	0.0	0.0
Tabellaria fenestrata (Lyngbye) Kutzing	0.0	0.0	30449.3	0.0
Tabellaria sp.	0.0	42.7	0.0	0.0
Thalassionema nitzschioides Hustedt	15019.3	14270.2	234789.5	32011.5
Thalassiosira aestivalis Gran and Angst	1344.3	71663.3	0.0	0.0
Thalassiosira decipiens (Grunow) Jorgensen	24.2	0.0	0.0	0.0
Thalassiosira gravida Cleve	284.3	58.7	256.3	59.0
Thalassiosira nordenskioldii Cleve	7416.8	40822.3	0.0	0.0
Thalassiosira rotula Meunier	72.2	756.6	0.0	21.4
Thalassiosira spp.	131300.2	35274.2	122329.5	72674.2
Thalassiothrix frauenfeldii Grunow	0.0	18.7	0.0	0.0
Centric diatoms <20 µm	117907.3	299080.8	181120.9	94680.6
Centric diatoms >20 - <100 µm	16901.6	3272.2	7252.2	1068.4
Pennate diatoms <20 µm	45056.1	14358.3	113676.0	290826.6
Pennate diatoms >20 µm	8606.1	4441.2	8986.4	15501.9

Table 3. (continued)

	W	S	S	F
DINOPHYCEAE				
Amphidinium acutissimum Schiller	68.3	5.4	0.0	0.0
Amphidinium acutum Lahmann	116.1	0.0	0.0	0.0
Amphidinium sp.	27208.2	8796.0	0.0	0.0
Ceratium fusus (Ehrenberg) DuJardin	8.1	81.5	0.0	0.0
Ceratium lineatum (Ehrenberg) Cleve	2.1	65.6	728.2	727.3
Ceratium tripos (Muller) Nitzsch	0.0	125.6	44.4	0.0
Cladopyxis caryophyllum (Kofoid) Pavillard	0.0	5.4	0.0	0.0
Cochlodinium sp.	0.0	0.0	161847.5	0.0
Dinophysis acuta Ehrenberg	0.0	44.3	0.0	0.0
Dinophysis ovum Schutt	0.0	0.0	0.0	2.7
Dinophysis punctata Jorgensen	12.1	42.7	77.5	4.0
Dinophysis sp.	124.5	544.7	394.1	0.0
Gonyaulax digitalis (Pouchet) Kofoid	0.0	0.0	26.8	0.0
Gonyaulax sp.	392.7	69.4	69.5	0.0
Gymnodinium nelsonii Martin	14.2	0.0	316.6	29.6
Gymnodinium sp.	2377.8	13516.9	34764.8	68121.8
Gyrodinium sp.	180.6	151.4	1.4	8066.2
Heterocapsa triquetra (Ehrenberg) Stein	14943.1	30722.6	0.0	50.8
Katodinium sp.	0.0	0.0	0.0	558.5
Noctiluca miliaris Suriray	0.0	0.0	0.0	14.9
Prorocentrum compressum (Bailey) Abe	64.3	5.4	60.3	105.8
Prorocentrum micans Ehrenberg	1788.1	7321.1	4141.0	665.5
Prorocentrum minimum (Pavillard) Schiller	1303.0	97810.6	8063.0	2477.0
Prorocentrum sp.	261.8	0.0	0.0	0.0
Prorocentrum triestinum Schiller	8.2	0.0	0.0	316.3
Protoperidinium bipes (Paulsen) Balech	0.0	5.4	0.0	2.7
Protoperidinium brevipes (Paulsen) Balech	614.7	0.0	1279.3	10.7
Protoperidinium depressum (Bailey) Balech	0.0	5.5	0.0	40.2
Protoperidinium diabolim (Cleve) Balech	0.0	6.8	13.4	0.0
Protoperidinium granii (Ostenfeld) Balech	48.5	61.8	116.6	18.9
Protoperidinium oceanicum (VanHoffen) Balech	8.1	1237.5	13.5	5.4
Protoperidinium sp.	1691.3	8703.9	1415.2	1836.6
Scrippsiella trochoidea (Stein) Loeblich III	24.1	0.0	0.0	53.5
Dinoflagellate cysts	270.0	530.0	1353.5	10.7
Unidentified dinoflagellates	0.0	0.0	0.0	2.1
HAPTOPHYCEAE				
Anthosphaera sp.	0.0	0.0	2827.4	0.0
Emiliania huxleyi (Lohmann) Hay and Mohler	1728.0	14660.0	21047.4	10655.2
Rhabdosphaera hispida Lohmann	0.0	890.1	628.3	0.0

Table 3. (continued)

	W	S	S	F
CHRYSOPHYCEAE				
Calycomonas ovalis Wulff	172349.5	205061.4	451430.4	116491.1
Calycomonas wulfii Conrad and Kufferath	9371.8	16274.8	9886.3	7366.6
Dictyocha fibula Ehrenberg	0.0	0.0	5048.3	16.1
Distephanus speculum (Ehrenberg) Haekel	8.1	0.0	0.0	0.0
CYANOBACTERIA				
Anacystis marina (Hansg) Drouet and Daily	0.0	0.0	24412.0	0.0
Anacystis sp.	0.0	0.0	10471.1	0.0
Gomphosphaera aponina Kutzing	1177.7	5.4	7749.0	2208.5
Microcystis spp.	13585.7	68559.2	452352.5	37516.6
Nostoc commune Vaucher	0.0	28598.0	0.0	0.0
Oscillaroria sp. #1	0.0	0.0	0.0	10.7
Oscillatoria sp. #2	0.0	4.0	12080.0	2.7
Spirulina subsalsa Oersted	0.0	0.0	14.2	0.0
EUGLENOPHYCEAE				
Euglena	4.1	3391.0	1256.5	1960.5
Eutreptia lanowii Steuer	1884.8	0.0	4188.5	0.0
Eutreptia sp.	0.0	0.0	14768.6	450.2
Eutreptia viridis Perty	1407.6	8556.1	2510.6	7227.8
CHLOROPHYCEAE				
Ankistrodesmus sp.	0.0	5288.0	0.0	0.0
Chlorella sp. #1	23918.8	24669.2	3255.0	3255.0
Chlorella sp. #2	4273.3	129423.4	0.0	0.0
Crucigenia sp.	0.0	170.7	0.0	0.0
Crucigenia tetrapedia (Kirchner) West and West	0.0	85.4	0.0	0.0
Scenedesmus quadricauda (Turpin) Brebisson	0.0	64.1	0.0	0.0
Scenedesmus sp.	0.0	1.4	42.7	0.0
CRYPTOPHYCEAE				
Cryptomonas sp.	92031.1	83780.6	166601.8	167716.0
PRASINOPHYCEAE				
Pyramimonas sp.	4832.3	1918.0	1047.1	1636.2
Pyramimonas torta Conrad and Kufferath	0.0	0.0	0.0	5390.9
Tetra[illegible]is sp.	0.0	22.6	14.2	0.0

Table 3. (continued)

	W	S	S	F
OTHERS (PICOPLANKTON)				
Green cells <3 µm	1943932.1	2309389.2	3288843.5	5609266.8
Green cells 3-5 µm	39076.5	123181.5	230887.0	127520.8
Green cells 5-10 µm	33315.6	80460.5	44163.5	17223.1
Micro-phytoflagellates <10 µm	2579.0	24326.0	18575.6	67200.5
Micro-phytoflagellates >10 µm	3052.0	0.0	0.0	589.0

Table 4. Average seasonal cell concentrations (no/l) at Stations 6 and 7, between February 1982 through December 1983.

	W	S	S	F
BACILLARIOPHYCEAE				
Achnanthes subsalsoides Hustedt	0.0	5.4	0.0	0.0
Actinoptychus senarius Ehrenberg	4.1	2.7	0.0	36.4
Amphora sp.	2001.3	899.0	16.1	20.3
Asterionella formosa Hassall	0.0	149.4	0.0	0.0
Asterionella glacialis Castracane	299831.7	68662.6	10.7	646.3
Bacillaria paxillifer (Muller) Hendey	16.1	0.0	0.0	0.0
Biddulphia alternans (Bailey) Van Heurck	235.7	0.0	0.0	37.5
Biddulphia mobiliensis (Bailey) Grunow	0.0	0.0	5.4	2.7
Biddulphia sinensis Greville	18.2	0.0	0.0	4.1
Biddulphia sp.	0.0	0.0	0.0	5.4
Cerataulina pelagica (Cleve) Hendey	24123.1	52013.0	21.5	52.1
Chaetoceros affine Lauder	0.0	0.0	0.0	761.5
Chaetoceros compressum Lauder	14815.6	613.5	0.0	491.0
Chaetoceros curvisetum Cleve	20.1	0.0	0.0	0.0
Chaetoceros danicum Cleve	0.0	90.7	42.8	81.8
Chaetoceros debile Cleve	905186.8	137208.8	21.4	17.4
Chaetoceros decipiens Cleve	0.0	3769.7	0.0	6692.3
Chaetoceros pendulum Karsten	0.0	32.2	21.4	1.4
Chaetoceros sp.	20505.7	148115.0	10225.8	7081.1
Chaetoceros subtile Cleve	1137.0	25130.8	7294.0	5842.0
Cocconeis sp.	0.0	0.0	0.0	349.0
Corethron criophilum Castracane	56.1	0.0	0.0	5183.5
Coscinodiscus centralis Ehrenberg	1784.3	5.4	0.0	356.0
Coscinodiscus lineatus Ehrenberg	0.0	37.5	0.0	0.0
Coscinodiscus marginatus Ehrenberg	0.0	32.0	0.0	16.0
Coscinodiscus oculus iridis Ehrenberg	0.0	0.0	0.0	5.4
Coscinodiscus sp.	619.6	888.5	204.4	426.2
Coscinosira polychorda (Gran) Gran	284.3	0.0	0.0	0.0
Cyclotella spp.	70379.6	646673.4	399629.5	132224.4
Cylindrotheca closterium (Ehrenberg) Reiman and Lewin	6412.0	4869.0	11697.6	13211.5
Diploneis sp.	8.1	0.0	10.7	0.0
Ditylum brightwellii (West) Grunow	60862.5	12824.7	72.3	391.4
Fragilaria sp.	604.2	0.0	0.0	502.6
Grammatophora sp.	2910.7	1256.5	3141.4	0.0
Guinardia flaccida (Castracane) Peragallo	533.3	53.6	0.0	0.0
Gyrosigma fasciola (Ehrenberg) Cleve	313.2	21.5	8.1	287.5
Leptocylindrus danicus Cleve	10595.6	3009.3	40.3	1292.3
Leptocylindrus minimus Gran	12772.7	55507.7	133313.0	152727.0
Licmophora sp.	16.2	21.5	16.0	0.0
Lithodesmium undulatum Ehrenberg	0.0	0.0	0.0	5.4

Table 4. (continued)

	W	S	S	F
Melosira granulata (Ehrenberg) Ralfs	0.0	394.7	21.4	37.5
Melosira nummuloides (Dillwyn) Agardh	4.1	0.0	0.0	26.8
Melosira sp.	0.0	0.0	0.0	26.8
Navicula cancellata Donkin	471.3	0.0	0.0	0.0
Nitzschia delicatissima Cleve	0.0	20.0	0.0	0.0
Nitzschia gracillima Heiden and Kolbe	0.0	0.0	0.0	34.7
Nitzschia longissima (Brebisson) Ralfs	0.0	0.0	21.4	21.5
Nitzschia pungens Grunow	233685.1	112659.5	680.4	1575.9
Nitzschia seriata Cleve	0.0	69.5	0.0	0.0
Paralia sulcata (Ehrenberg) Cleve	4310.3	345.8	245.6	448.6
Plagiogramma staurophorum (Gregory) Heilberg	0.0	0.0	0.0	136.6
Pleurosigma angulatum (Quekett) W. Smith	401.0	679.5	51.0	112.5
Pleurosigma sp.	420.8	144.8	382.0	1025.3
Rhaphoneis amphiceros Ehrenberg	12.2	5.42	8.1	390.8
Rhaphoneis sp.	0.0	1.4	0.0	0.0
Rhaphoneis surirella (Ehrenberg) Grunow	56.1	32.0	0.0	0.0
Rhizosolenia alata Brightwell	0.0	18.8	0.0	2.7
Rhizosolenia alata f. *gracillima* (Cleve) Grunow	12.2	0.0	0.0	243.5
Rhizosolenia calcar-avis Schultze	524.6	80.3	10.7	53.5
Rhizosolenia delicatula Cleve	32837.6	28592.3	202.8	2974.5
Rhizosolenia fragilissima Bergon	84252.8	156951.3	1587.5	328.5
Rhizosolenia hebetata f. *semispina* (Hensen) Gran	0.0	0.0	0.0	10.7
Rhizosolenia imbricata Brightwell	84.3	108.4	0.0	32.1
Rhizosolenia setigera Brightwell	5373.2	2861.6	21.4	420.5
Rhizosolenia stolterfothii Peragallo	325.0	0.0	0.0	20667.3
Schroederella delicatula (Peragallo) Pavillard	888.5	90.7	0.0	0.0
Skeletonema costatum (Greville) Cleve	254748.0	176787.0	403479.8	61075.1
Stephanopyxis turris (Greville) Ralfs	0.0	70.8	0.0	0.0
Streptotheca thamensis Shrubsole	0.0	0.0	0.0	197.5
Striatella unipunctata (Lyngbye) Agardh	0.0	5.4	0.0	0.0
Synedra sp.	0.0	70.9	0.0	0.0
Tabellaria fenestrata (Lyngbye) Kutzing	0.0	0.0	2232.5	288.0
Tabellaria sp.	0.0	0.0	0.0	37.4
Thalassionema nitzschioides Hustedt	13492.5	5524.5	44411.4	14232.8
Thalassiosira aestivalis Gran and Angst	7575.5	97470.4	0.0	273.2
Thalassiosira decipiens (Grunow) Jorgensen	16.2	0.0	0.0	0.0
Thalassiosira gravida Cleve	1970.6	0.0	42.7	8.1
Thalassiosira nordenskioldii Cleve	262970.0	63903.9	0.0	0.0
Thalassiosira rotula Meunier	0.0	42.8	0.0	0.0
Thalassiosira spp.	211148.2	34480.5	178540.4	29297.5
Triceratium sp.	0.0	10.7	0.0	0.0
Centric diatoms <20 µm	131954.1	284699.0	372307.3	163573.0
Centric diatoms >20 - <100 µm	26942.0	17323.0	3856.5	1394.5
Pennate diatoms <20 µm	53374.5	51453.5	89790.0	86974.8
Pennate diatoms >20 µm	20000.0	12113.8	25897.0	17645.6

Table 4. (continued)

	W	S	S	F
DINOPHYCEAE				
Amphidinium acutissimum Schiller	942.5	21.4	0.0	0.0
Amphidinium sp.	13748.2	35183.1	598.4	0.0
Ceratium fusus (Ehrenberg) DuJardin	0.0	5.4	2.7	0.0
Ceratium lineatum (Ehrenberg) Cleve	4.1	20.1	643.1	215.1
Ceratium tripos (Muller) Nitzsch	0.0	2.7	0.0	0.0
Cochlodinium sp.	0.0	0.0	260552.1	14360.5
Dinophysis acuminata Claparede and Lachmann	0.0	5.42	0.0	0.0
Dinophysis acuta Ehrenberg	0.0	5.5	0.0	0.0
Dinophysis ovum Schutt	0.0	0.0	0.0	2.7
Dinophysis sp.	32.2	189.8	0.0	0.0
Gonyaulax diegensis Kofoid	0.0	0.0	5.4	0.0
Gonyaulax sp.	0.0	0.0	7576.6	0.0
Gonyaulax tricantha Jorgensen	0.0	0.0	149.4	32.0
Gymnodinium nelsonii Martin	50.2	0.0	1091.3	1347.0
Gymnodinium sp.	1418.0	12498.8	28730.8	14756.5
Gyrodinium sp.	16.2	13.4	10.9	82.8
Heterocapsa triquetra (Ehrenberg) Stein	89421.2	67662.6	10.7	85.5
Katodinium sp.	0.0	0.0	6282.7	571.2
Oxytoxum sceptrum (Stein) Schroder	0.0	0.0	1.1	0.0
Oxytoxum sp.	0.0	0.0	2.7	0.0
Prorocentrum compressum (Bailey) Abe	22.3	0.0	2.7	96.6
Prorocentrum micans Ehrenberg	28.5	7146.8	3889.3	89.8
Prorocentrum minimum (Pavillard) Schiller	3382.2	174878.3	12390.4	5356.2
Prorocentrum sp.	0.0	0.0	0.0	1.2
Prorocentrum triestinum Schiller	0.0	0.0	0.0	18.8
Protoperidinium bipes (Paulsen) Balech	0.0	10.7	0.0	10.7
Protoperidinium breve (Paulsen) Balech	0.0	0.0	0.0	32.0
Protoperidinium brevipes (Paulsen) Balech	0.0	0.0	58.9	10.7
Protoperidinium depressum (Bailey) Balech	0.0	1.4	0.0	10.7
Protoperidinium granii (Ostenfeld) Balech	0.0	25.6	149.8	18.8
Protoperidinium sp.	2156.8	52153.6	2029.4	253.4
Scrippsiella trochoidea (Stein) Loeblich III	0.0	0.0	3141.4	18.8
Dinoflagellate cysts	4.13	1434.2	15083.9	16.2
Unidentified dinoflagellates	554.5	216.7	0.0	0.0
HAPTOPHYCEAE				
Anthosphaera sp.	0.0	0.0	16.1	0.0
Emiliania huxleyi (Lohmann) Hay and Mohler	1477.8	19216.6	125085.6	12513.1
Hymenomonas sp.	0.0	16.2	0.0	0.0
Rhabdosphaera hispida Lohmann	0.0	216.7	966.6	0.0
Rhabdosphaera sp.	0.0	0.0	0.0	174.5
Unidentified coccolithophores	0.0	747.5	0.0	95.2

Table 4. (continued)

	W	S	S	F
CHRYSOPHYCEAE				
Calycomonas ovalis Wulff	156937.7	237986.1	244656.8	173798.0
Calycomonas wulfii Conrad and Kufferath	29839.5	24662.7	39703.5	20380.8
Dictyocha fibula Ehrenberg	6.2	0.0	1933.2	0.0
Ochromonas sp.	0.0	8.1	14.2	0.0
Olisthodiscus spp.	0.0	3.2	126.8	10.7
CYANOBACTERIA				
Anacystis marina (Hansg) Drouet and Daily	0.0	0.0	10015.2	0.0
Gomphosphaera aponina Kutzing	8651.0	87232.1	24502.5	5691.9
Merismopedia sp.	0.0	17.5	0.0	0.0
Microcystis spp.	0.0	20015.1	517482.2	70591.8
Nostoc commune Vaucher	0.0	5654.5	0.0	0.0
Oscillatoria sp. #1	4.1	0.0	0.0	0.0
Oscillatoria sp. #2	0.0	21.5	3418.9	0.0
Oscillatoria submembranacea Ardissone and Strafforella	0.0	0.0	24.2	16.0
EUGLENOPHYCEAE				
Euglena sp.	204.6	32886.6	22247.5	285.6
Eutreptia lanowii Steuer	0.0	16.1	1196.7	0.0
Eutreptia sp.	1109.0	42.7	96125.2	0.0
Eutreptia viridis Perty	3025.0	8243.4	3370.0	4553.8
Phacus sp.	0.0	0.0	4.2	0.0
Trachelomonas sp.	0.0	16.2	0.0	0.0
CHLOROPHYCEAE				
Ankistrodesmus sp.	0.0	3769.7	0.0	0.0
Chlorella sp.	16335.0	29294.6	0.0	0.0
Crucigenia quadrata Morren	0.0	170.7	0.0	0.0
Crucigenia tetrapedia (Kirchner) West and West	0.0	15078.5	0.0	0.0
Scenedesmus acumin (Lagerheim) Chodat	32.1	0.0	0.0	0.0
Scenedesmus armatus (Chodat) G. M. Smith	32.1	0.0	0.0	0.0
Scenedesmus quadricauda (Turpin) Brebisson	0.0	5037.0	0.0	0.0
Scenedesmus sp.	0.0	1256.5	0.0	3.9
CRYPTOPHYCEAE				
Cryptomonas spp.	117465.2	212803.0	308477.5	199319.8
PRASINOPHYCEAE				
Pyramimonas sp.	1893.1	966.6	0.0	375.0
Pyramimonas torta Conrad and Kufferath	4.1	0.0	897.5	1163.5
Tetraselmis gracilis (Kylin) Butcher	0.0	8.4	3.2	0.0

Table 4. (continued)

	W	S	S	F
OTHERS (PICOPLANKTON)				
Green cells <3 μm	2513160.6	2651092.3	4256137.6	5106708.9
Green cells 3-5 μm	41178.0	123892.4	166151.6	108742.0
Green cells 5-10 μm	17986.6	57976.3	67680.1	18128.4
Micro-phytoflagellates <10 μm	5411.4	32694.8	45058.1	23290.3

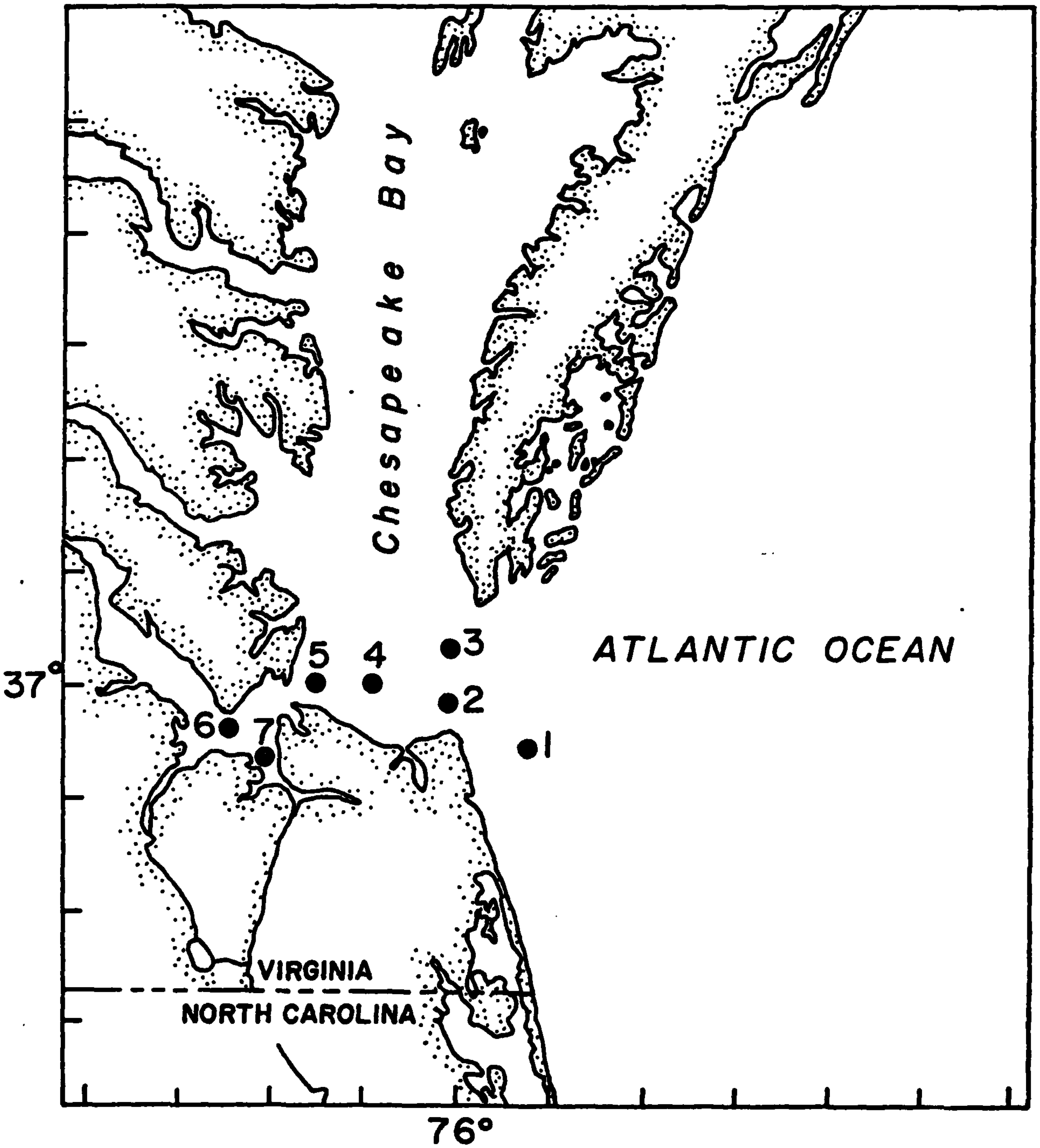


Figure 1. Station locations during the study.

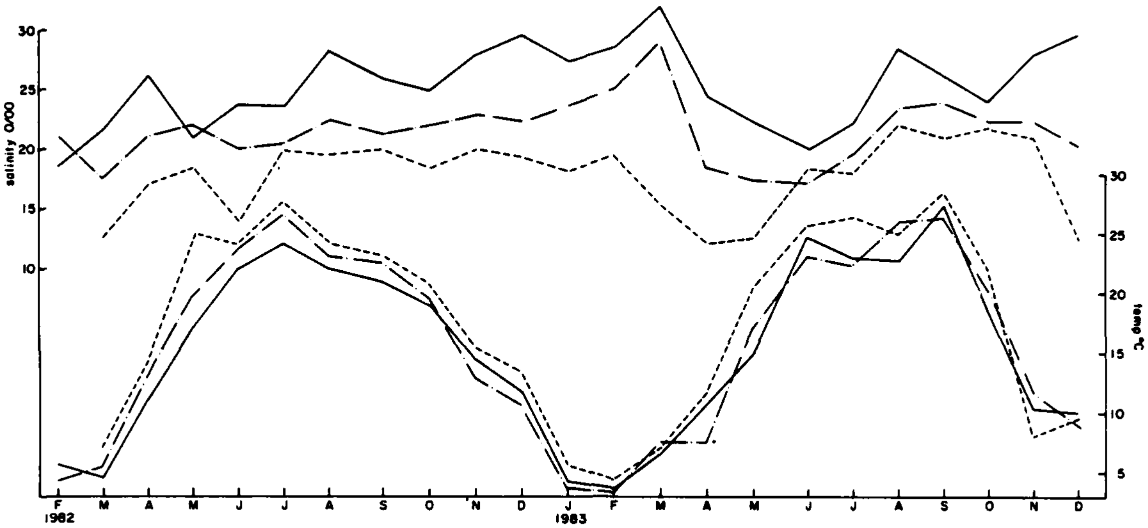
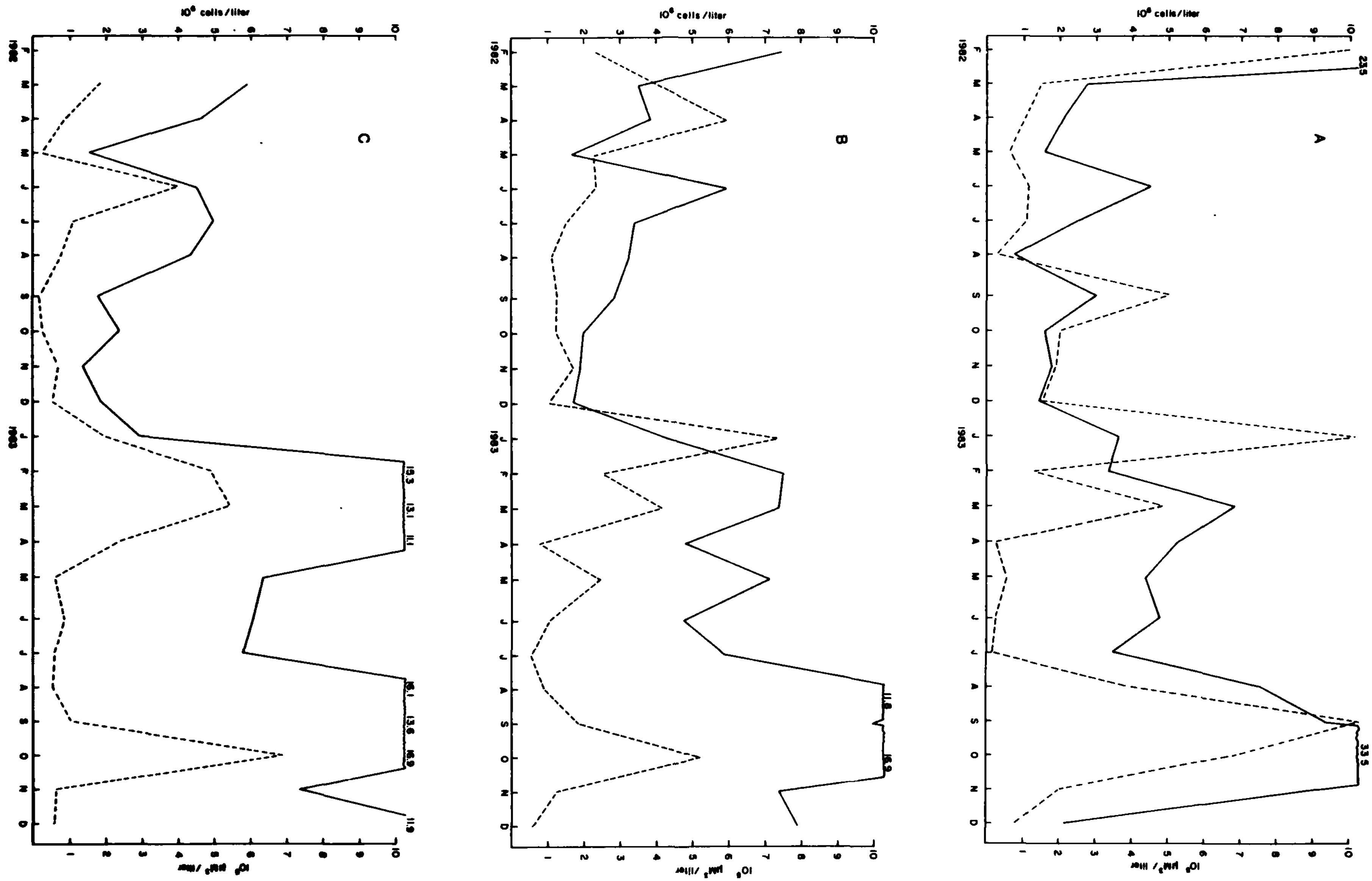
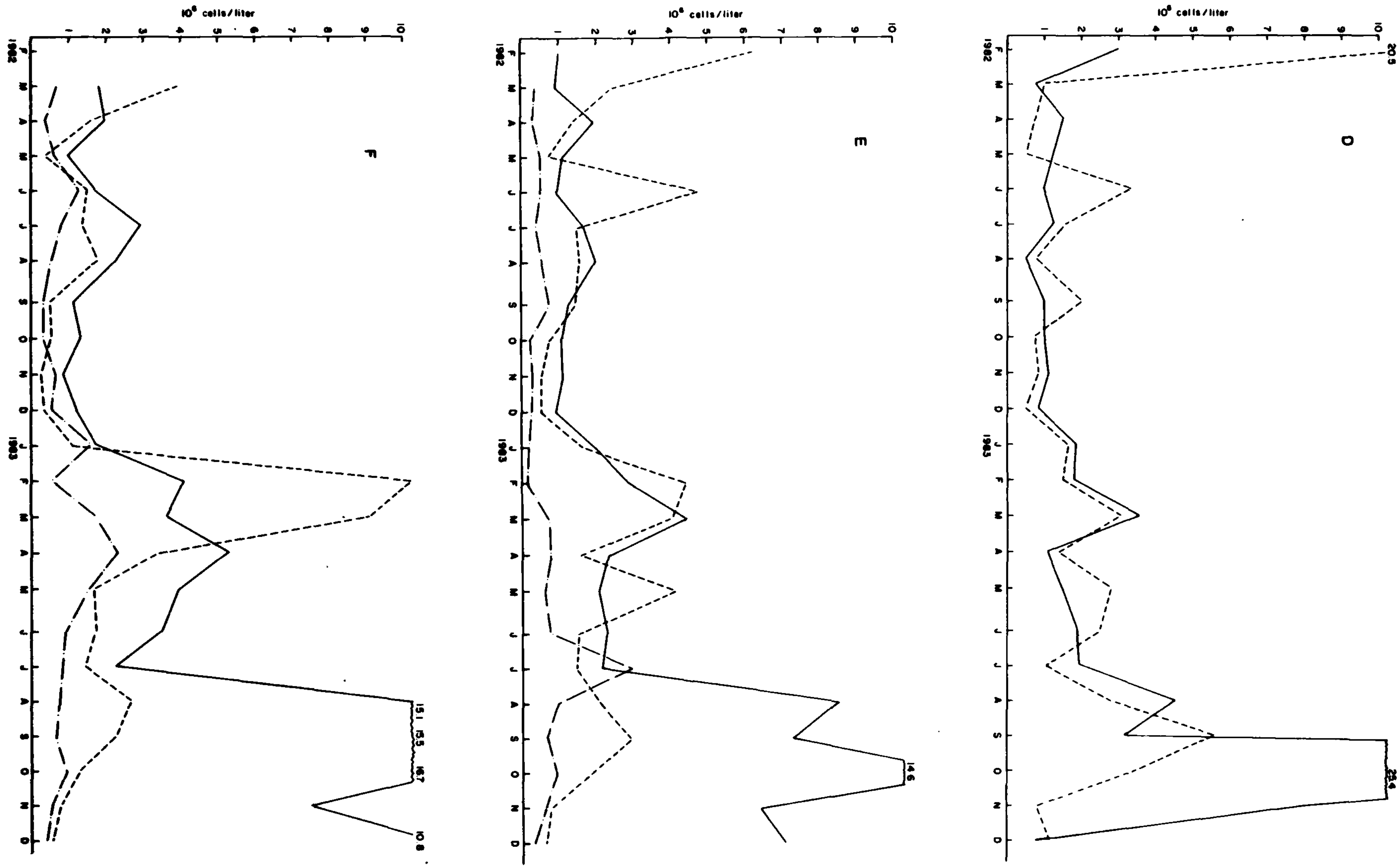


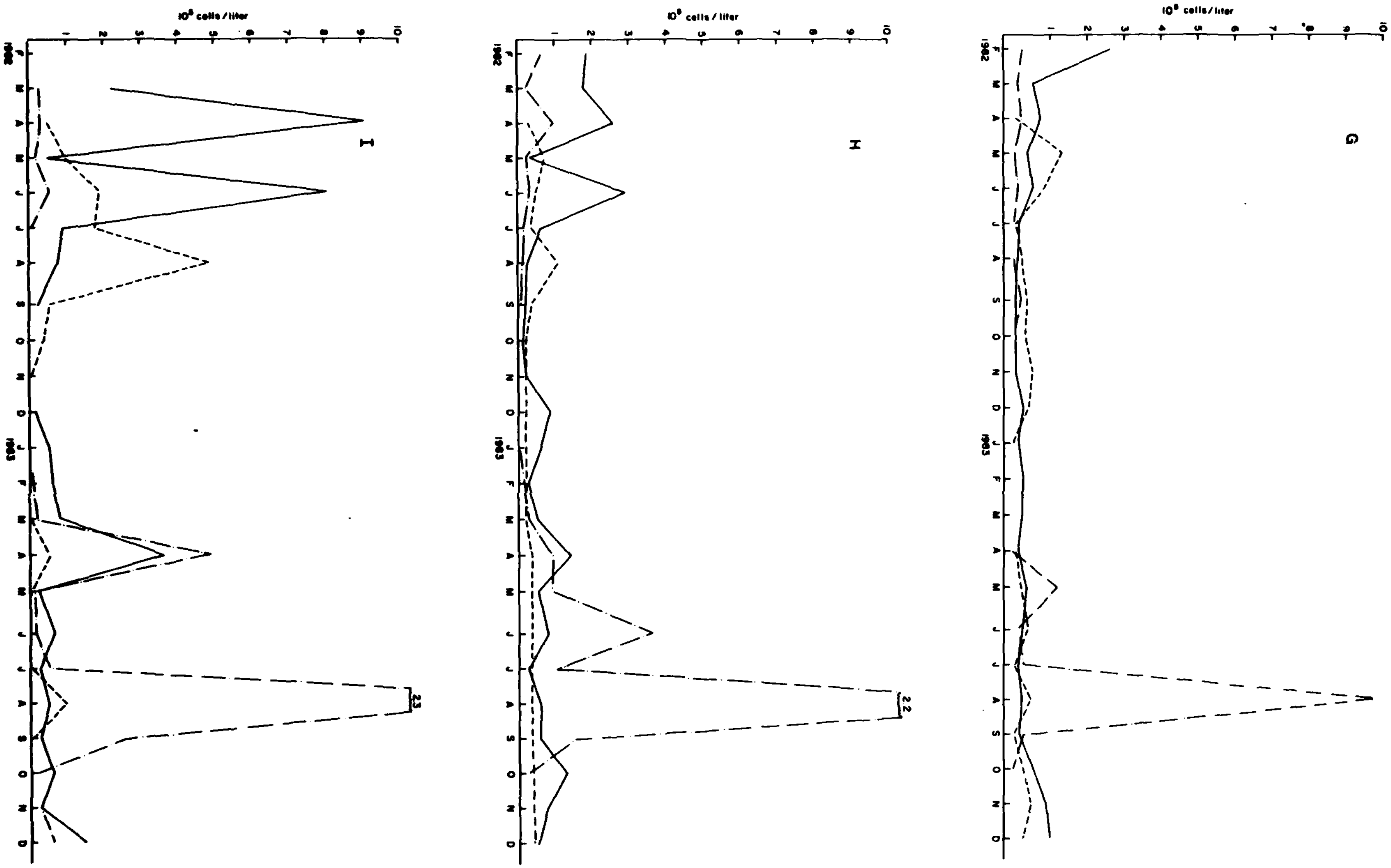
Figure 2. Salinity ($^{o}/oo$) and temperature records during the study for station 1 (——) outside the Bay entrance, 4 (—·—) in the lower Chesapeake Bay, and 7 (----) in Hampton Roads.



Figures 3(A), 4(B), and 5(C). Combined surface and bottom averages for total phyto-plankton cell concentrations (——) and cell volume (– – –), at the shelf station (A), lower Bay stations (B), and Hampton Roads stations (C).



Figures 6(D), 7(E), and 8(F). Combined surface and bottom averages for total cell concentrations of picoplankton (———), diatoms (– – –), and cryptomonads (–·–·), at the shelf station (D), lower Bay stations (E), and Hampton Roads stations (F).



Figures 9(G), 10(H), and 11(I). Combined surface and bottom averages for total cell concentrations of dinoflagellates (———), haptophytes (— — —), and cyanobacteria (—·—·), at the shelf station (G), stations in the lower Bay (H), and Hampton Roads stations (I).

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